DAIRY FOODS

Cheddar and Cheshire Cheese Rheology[1]

M. H. TUNICK, E. J. NOLAN, J. J. SHIEH, J. J. BASCH, M. P. THOMPSON, B. E. MALEEFF,
and V. H. HOLSINGER
US Department of Agriculture, ARS
Eastern Regional Research Center
Philadelphia, PA 19118

ABSTRACT

Textural differences between Cheddar and Cheshire cheeses were examined rheologically to provide a means of distinguishing these two English cheeses. Body breakdown of a 60-wk Cheshire sample occurred at a lower strain than did a 20-wk sample, whereas a 60-wk Cheddar sample did not break down under the same conditions. All cheeses followed the Arrhenius equation, and the energy of activation obtained varied with age and type of cheese. Other analytical techniques showed differences between the samples but were not suitable for distinguishing one type of cheese from the other.

(Key words: rheology, viscosity, cheese)

INTRODUCTION

Various types of cheese cannot always be differentiated using standard analytical techniques. This presents a problem when the possibility of mislabeling has to be investigated. English Cheshire is usually sold between 2 wk and 10 mo after manufacture, and English Cheddar is often sold in the US after 1 yr of aging (7). Thus, an electrophoretic analysis of their proteins can be difficult because of different ages and levels of protein breakdown. Compositional differences between Cheddar and Cheshire are slight, because both typically contain 36 to 38% moisture, 23 to 25% protein, and 30 to 33% fat (7).

Cheshire cheese is manufactured to keep the curd particles separate, whereas Cheddar curd particles are spread out and matted together in the cheddaring process (9). The resultant textural differences make rheological measurements a logical choice for distinguishing the two cheeses. Some recent rheological work has been reported on Cheddar (2, 3, 6) and Cheshire (3), but a comparison of the two for identification purposes has not been made. In this study, rheological and other analytical methods were compared in an attempt to differentiate between English-made Cheddar and Cheshire cheeses.

MATERIALS AND METHODS

The cheese samples were manufactured in England and purchased locally. The Cheshire cheese was 20 wk old when rheological tests were first performed on it and 60 wk old when follow-up tests were made. The Cheddar was 60 wk old when examined rheologically. A 20-wk Cheddar was unavailable, since Cheddar is usually imported from England after a year of aging. Samples were tempered at room temperature for 5 h prior to rheological work.

The viscoelastic properties of the cheeses were examined with a Rheometrics Dynamic Analyzer 700 (Rheometrics, Inc., Piscataway, NJ), using a 0 to 200 g-cm torque transducer and parallel plates with a diameter of 2.50 cm. A cork borer was used to obtain a sample disk with a diameter of 2.5 cm and a height of 4 mm. To prevent slippage, two drops of cyanoacrylate bonding agent were spread evenly over the lower plate, upon which the sample was placed. Two drops of bonding agent were then spread evenly over the cheese, and the upper plate was lowered on top of it. The experiments were carried out in an environmental chamber at 20°C, unless otherwise specified. The data obtained included the two components of the shear modulus G*: the elastic (storage modulus) component G' and the viscous (loss modulus) component G''. Both were measured in dynes per square centimeter. The complex viscosity η^* (in poises) and the frequency ω (in

rad/s) were also measured. These parameters are related as follows:

$$(|G^*|)^2 = (G')^2 + (G'')^2$$

$$\text{and } |\eta^*| = |G^*|/\omega$$

With ω set at 1.0 rad/s, values of G', G'', and η^* were obtained as the percentage of strain values were varied, resulting in a strain sweep.

Extracted and freeze-dried cheese proteins were dissolved in Tris-EDTA buffer and characterized by SDS-PAGE. Two methods were used for preparing and developing the gels (1, 10). The relative amounts of protein in the resultant bands were measured with a Bio-Rad Model 620 (Bio-Rad Laboratories, Richmond, CA) densitometer.

Specific heat at 60°C was measured with a Perkin-Elmer DSC-2 differential scanning calorimeter (Perkin-Elmer Corp., Norwalk, CT). Duplicate samples weighing 2 to 5 mg were hermetically sealed in volatile sample pans, placed in the instrument at 37°C, and heated to 67°C at 10°C/min. The deflection from the baseline at 60°C was divided by sample weight and heating rate to obtain specific heat.

Scanning electron microscopy (SEM) was used to determine cheese microstructure. Cheese pieces measuring 5 mm on a side were chemically stabilized with buffered glutaraldehyde and osmium tetroxide and gradually dehydrated in increasing concentration of ethanol in water. The samples were quick frozen in liquid nitrogen and fractured with a scalpel to expose an uncut surface. Samples were finally dried by the critical point method, mounted on SEM stubs with silver paint, and sputter-coated with 15 nm of gold-palladium. The prepared samples were examined with a JEOL JSM-840A SEM operating at 5 kV.

RESULTS AND DISCUSSION

Percentages of the varieties of casein, as determined by PAGE, are shown in Table 1.

The relatively low percentage of α_{s1}-casein and β-casein in the Cheddar, and the elevated percentages of γ_2 + γ_3-caseins, are indicative of protein hydrolysis during ripening. The ages of the cheeses were confirmed by examining the levels of casein breakdown, but electrophoretic information alone cannot distinguish the two types of cheese.

The specific heat values of the Cheshire at 20 and 60 wk were .64 and .67 cal/g °K, respectively. The glycerides in cheese fat slowly crystallize with aging (8), and this probably accounts for the increase in specific heat. The specific heat of Cheddar at 60 wk was .72 cal/g °K, with the higher value being indicative of a stronger cheese structure. Specific heat determinations can be useful in differentiating the cheeses, but more data would be needed to prevent misidentification, since varying moisture levels can affect the results.

Scanning electron micrographs of the two cheeses are shown in Figure 1. The Cheshire had a smooth continuous protein network surrounding irregular lipid inclusions ranging from 2 to 30 μm across. The lipid inclusions in the Cheddar were 1 to 5 μm across, and the protein matrix was denser. These results showed clear differences between the two types of cheese, but the microstructures resemble those of some other cheeses. The microstructure of the Cheddar, for instance, was similar to those of Mozzarella samples analyzed in an earlier study (11). Therefore, SEM cannot be used by itself to tell Cheddar apart from Cheshire because of possible misidentification with other cheese varieties.

The rheological measurements demonstrated clear differences between the cheeses. The strain sweeps of the Cheshire cheeses after 20 and 60 wk are shown in Figures 2 and 3. Proteolysis during ripening results in decreased viscosity and elasticity of cheese (2, 4), and this effect is demonstrated in the downward shift of the G', G'', and η^* curves. Inflections are pre-

TABLE 1. Percentages of the various types of casein in 20-wk Cheshire and 60-wk Cheddar cheeses, as determined by densitometry of SDS-PAGE gels.

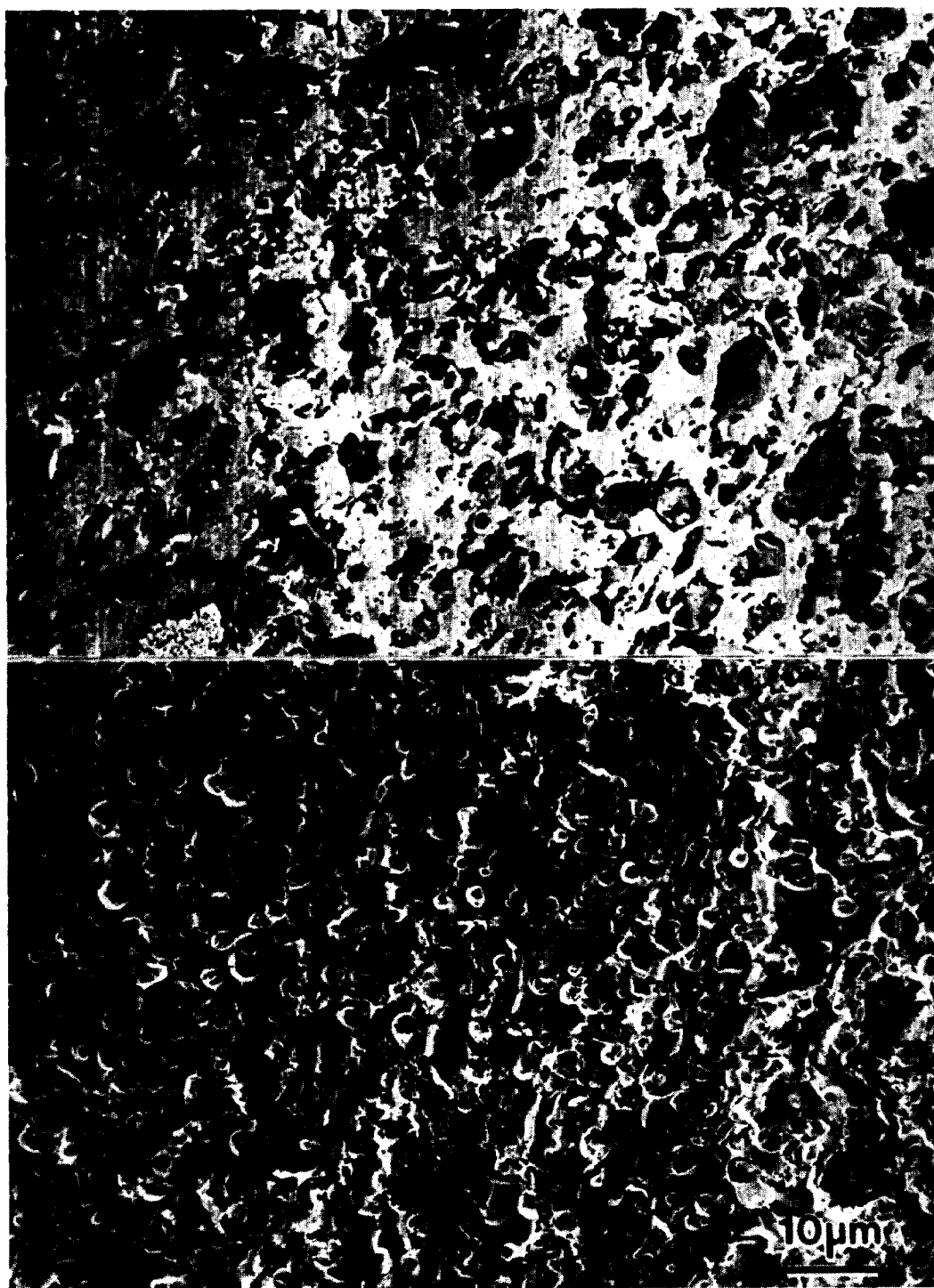| Sample	α_{s2}	α_{s1}	β	γ_1 Region	Para-κ	γ_2 + γ_3 Region
Cheshire	7.89	5.37	32.34	2.96	7.29	14.02
Cheddar	2.23	1.65	22.05	1.93	6.45	28.86

Figure 1. Scanning electron micrographs of 20-wk Cheshire cheese (top) and 60-wk Cheddar cheese.

TABLE 2. Values of complex viscosity (log η*) at various temperatures.

Temperature (°C)	log η*		
	20-wk Cheshire	60-wk Cheshire	60-wk Cheddar
20	6.05	5.94	6.19
25	5.90	5.71	5.74
30	5.64	5.50	5.40
35	5.24	5.23	5.00
40	4.91	4.96	4.60

sent in the curves at approximately 12% strain in the younger cheese and at roughly 8% strain in the older sample. The inflection suggests crumbliness resulting from body breakdown (8). The amount of stress the cheese can withstand before breakdown decreases during ripening (2, 8), which is evidenced by the shift with age of the inflection point. The strain sweep of 60-wk Cheddar cheese does not show such an inflection (Figure 4). At 0% strain, the values of G', G", and η* of the Cheddar are almost twice those of the 60-wk Cheshire. These findings are consistent with Cheshire being the crumblier of the two cheese types.

A linear region of G* was not present in any of the strain sweeps, but quasilinear behavior (an essentially constant G*) was observed at 2.5% strain in each of the samples. The values of η* for the cheeses at this strain were ob-

tained at various temperatures using a ω of 1.0 rad/s. The decrease in complex viscosity with increasing temperature is shown in Table 2. With each cheese, a plot of η* versus reciprocal of absolute temperature (1/T) produced a straight line which followed the Arrhenius equation:

$$\eta^* = A_{visc} \exp (E_{visc}/RT),$$

where A_{visc} is the pre-exponential factor, E_{visc} is the activation energy, and R is the gas constant (1.987 cal/°C mol). By converting η* to $\log_{10}$, E_{visc} is equal to the slope of the line multiplied by 2.303R. The Arrhenius equations and activation energies of the samples are shown in Table 3. The viscosity and energy of activation of the Cheshire decreased approximately 20% from 20 to 60 wk since the body of
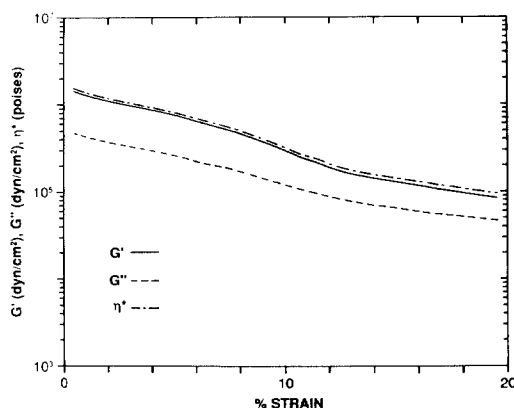

Figure 2. Strain sweep of 20-wk Cheshire cheese, with frequency (ω) = 1.0 rad/s. Elastic component G' (dyn/cm²), viscous component G" (dyn/cm²), and complex viscosity η* (poise) plotted versus percentage of strain.
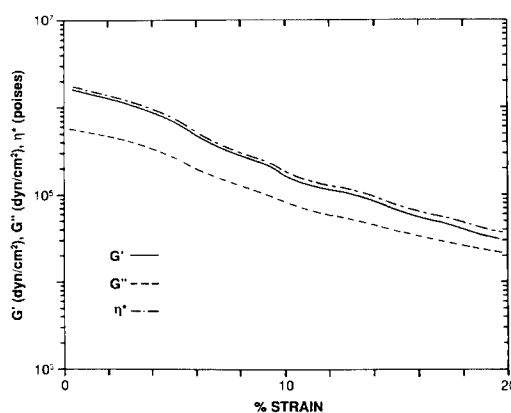

Figure 3. Strain sweep of 60-wk Cheshire cheese, with frequency (ω) = 1.0 rad/s. Elastic component G' (dyn/cm²), viscous component G" (dyn/cm²), and complex viscosity η* (poise) plotted versus percentage of strain.

TABLE 3. Arrhenius equations and activation energies (E_{visc}) of the cheeses.

Sample	Equation[1]	E_{visc}[2]
		(cal/mol)
20-wk Cheshire	log η^* = 5331/T - 12.05	24,400
60-wk Cheshire	log η^* = 4442/T - 9.20	20.250
60-wk Cheddar	log η^* = 7156/T - 18.24	32,750

[1]η^* = Complex viscosity (log η^*); T = temperature.

[2]E_{visc} = Slope × 2.303 R.

the cheese was breaking down. The higher E_{visc} value for the Cheddar indicates that its body breaks down less easily than that of Cheshire. In another study (6), a Cheddar sample of unknown age, but presumably less than 1 yr, had an E_{visc} of 36,700 cal/mol using the same conditions and instrumentation. Commercially available Cheshire cheese apparently will have an E_{visc} much lower than that of Cheddar.

Rheological properties of cheese are affected by its composition. For instance, the elasticity and firmness of cheese increases with decreasing fat content, and a cheese will become softer if its moisture content is elevated (5). Compositional variations and their effect on viscoelastic properties of cheese will be the subject of future research.

CONCLUSIONS

Measurements of rheological properties of Cheddar and Cheshire can be used to distin-

guish the two cheeses. The expected decreases with age in viscosity, elasticity, and body strength were observed with Cheshire. Body breakdown of Cheddar was not seen under the same conditions, and its energy of activation was much higher than that of Cheshire. Other analytical methods did not produce a reliable distinction between the two.

REFERENCES

1 Basch, J. J., F. W. Douglas, Jr., L. G. Procino, V.H. Holsinger, and H. M. Farrell, Jr. 1985. Quantitation of caseins and whey proteins of processed milks and whey protein concentrates, application of gel electrophoresis, and comparison with Harland-Ashworth procedure. J. Dairy Sci. 68:23.

2 Creamer, L. K., and N. F. Olson. 1982. Rheological evaluation of maturing Cheddar cheese. J. Food. Sci. 47: 631.

3 Dickinson, E., and I. C. Goulding. 1980. Yield behaviour of crumbly English cheeses in compression. J. Texture Stud. 11:51.

4 Lawrence, R. C., and J. Gilles. 1987. Page 27 in Cheese chemistry, physics and microbiology. Vol. 2. Major cheese groups. P. F. Fox, ed. Elsevier Appl. Sci. Publ., London, UK.

5 Luyten, H. 1988. The rheological and fracture properties of Gouda cheese. Ph.D. Diss., Wageningen Agric. Univ., Holland.

6 Nolan, E. J., J. J. Shieh, and V. H. Holsinger. 1989. A comparison of some rheological properties of Cheddar and pasteurized process American cheese. Proc. 5th Int. Congr. Eng. Food, Cologne, W. Germany.

7 Posati, L. P., and M. L. Orr. 1976. Composition of foods. Dairy and egg products. Agric. Res. Serv., US Dep. Agric., Washington, DC.

8 Prentice, J. H. 1987. Cheese rheology. Page 339 in Cheese chemistry, physics and microbiology. Vol. 1. General aspects. P. F. Fox, ed. Elsevier Appl. Sci. Publ., London, UK.

9 Scott, R. 1986. Cheese making practice. 2nd ed. Elsevier Appl. Sci. Publ., London, UK.

10 Thompson, M. P., D. P. Brower, and H. M. Farrell, Jr. 1987. Absence of detectable calmodulin in cow's milk by a modified gel electrophoresis method. J. Dairy Sci. 70:1134.

11 Tunick, M. H., J. J. Basch, B. E. Maleeff, J. F. Flanagan, and V. H. Holsinger. 1989. Characterization of natural and imitation Mozzarella cheeses by differential scanning calorimetry. J. Dairy Sci. 72:1976.
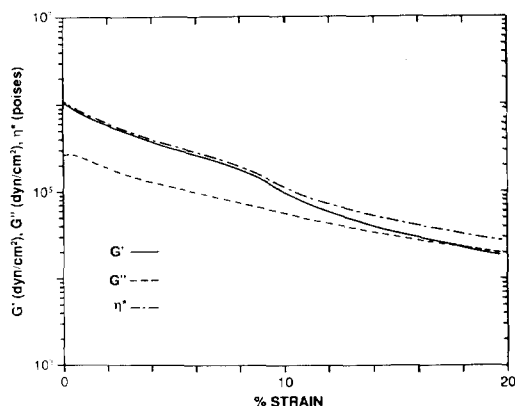
Figure 4. Strain sweep of 60-wk Cheddar cheese with frequency (ω) = 1.0 rad/s. Elastic component G' (dyn/cm^2), viscous component G" (dyn/cm^2), and complex viscosity η^* (poise) plotted versus percentage of strain.